

**Does the Resistive Tearing Instability Nonlinearly Evolve to a Fast Reconnection Mode?\***

**R.S. Steinolfson (U. Texas, Austin)**

A fundamental problem in applying linear tearing instability theory to the rapid processes (particle acceleration, heating) in flares has been the characteristically slow rate of reconnection. This problem can be at least partially overcome if the tearing mode nonlinearly evolves to a regime in which the reconnection rate is substantially enhanced, such as that for the Petschek configuration. This possibility has often been suggested, and some numerical simulations appear to provide support for such a view. We use numerical simulations to study the nonlinear evolution of the tearing instability and show that a fast Petschek-like regime may not be achieved. This conclusion follows when there are sufficient grid points within the diffusion region to completely resolve the nonlinear dynamical interactions in the diffusion layer. When the numerical resolution is not adequate, the solution does appear to approach a Petschek configuration. The resolved solution contains reverse flow vortices and current sheets, terminated with a current reversal, similar to those obtained by Syrovatsky (JETP, 33, 933, 1971).

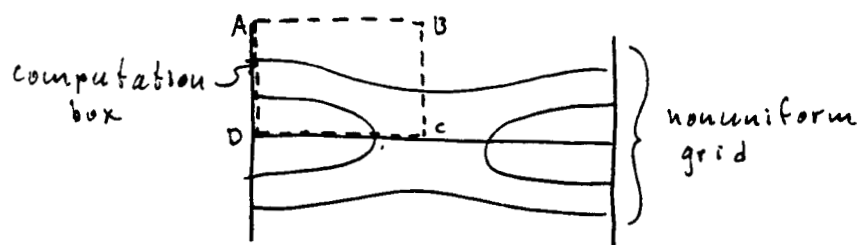
**\*Research supported by NASA and NSF. Computations performed at SDSC.**

Does the Resistive Tearing Instability  
Nonlinearly Evolve to a Fast Reconnection Mode?

R. S. Steinolfson  
Institute for Fusion Studies  
University of Texas, Austin

Results from two studies concerning the rate of reconnection of magnetic field lines are reported on. Both illustrate the need to numerically resolve the physical processes inside the diffusion layer in order to simulate the correct evolution.

The model assumes incompressible MHD with constant resistivity in a slab geometry. The time-dependent equations are solved numerically using a fully implicit method. A linearly growing mode provides the initial disturbance. Only one quadrant of the complete mode is simulated as shown in the sketch below:



The boundary conditions are-

B-C, C-D; symmetry

D-A; symmetry for the first study, outflow for the second

A-B; linear extrapolation although it is so far

removed from the tearing layer by the nonuniform grid that it has virtually no influence.

The results from the individual studies are as follows:

A. Nonlinear evolution of a linearly growing mode

The first set of plots below (indicated by ①) are for an unresolved diffusion layer while for the second ② sufficient resolution was used to correctly simulate the nonlinear effects of the resistive terms. The two solutions were started with the same linear mode and are compared after evolving for the same time period. The solution in set ① is simply an amplified linear mode, while that in set ② shows the development of reverse flow vortices.

ORIGINAL PAGE IS  
OF POOR QUALITY

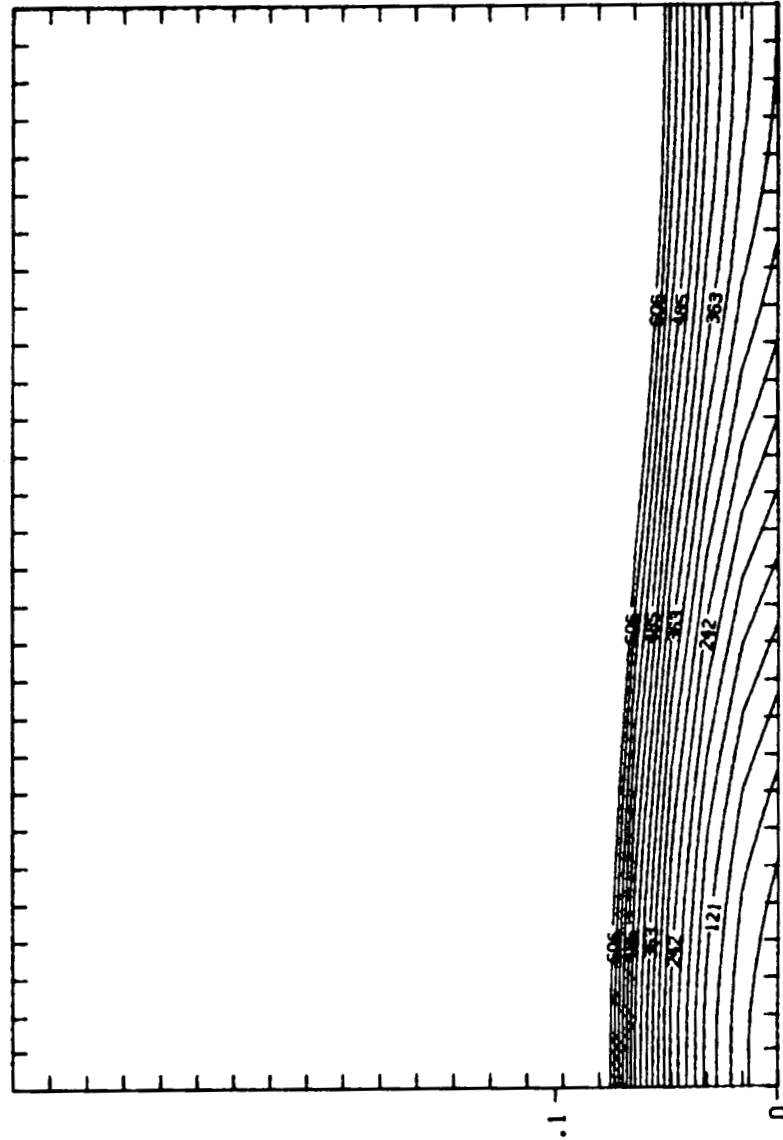
ORIGINAL PAGE IS  
OF POOR QUALITY

① Unresolved diffusion layer

TIME = 2.019E+02 TAUH = 7.857E+00 SEC.  
CONSTANT FLUX CURVES

6.3E+01

0.1

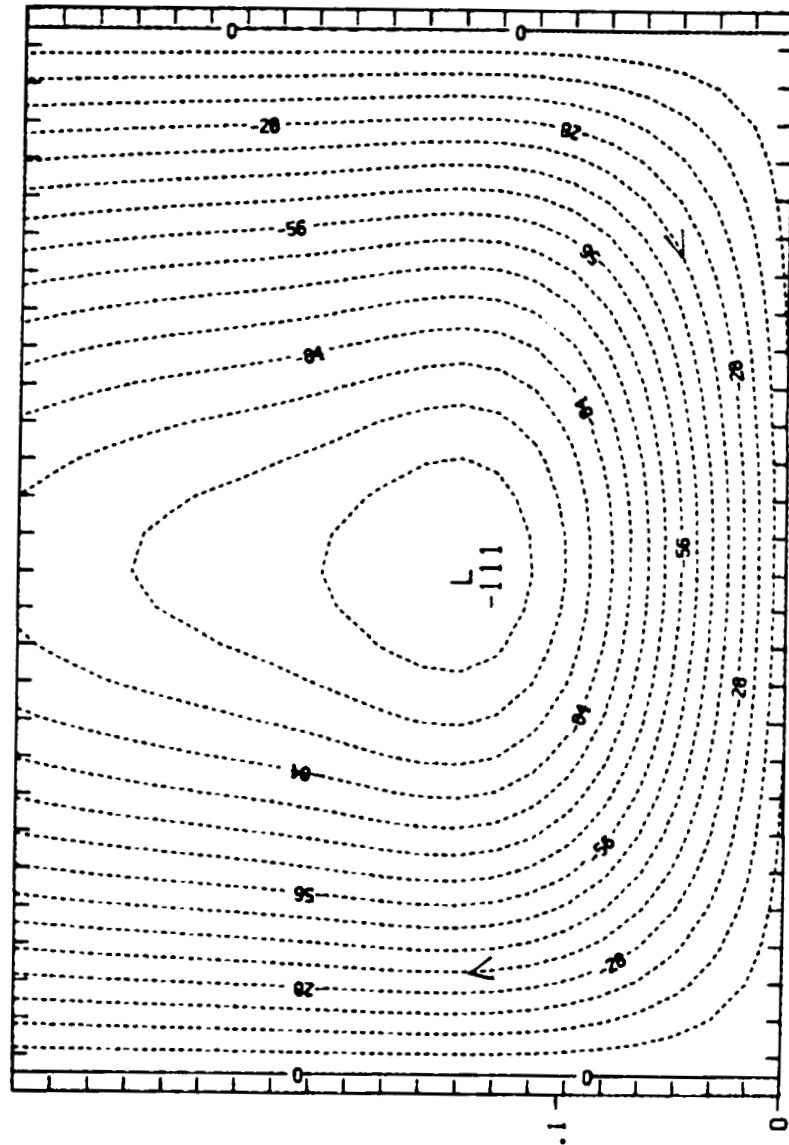


CONTOUR FROM 0. TO .6050E+02 CONTOUR INTERVAL OF .30250E+02 P113.31= .11400E+02 UNITS.3 SQUARED BY 100000

228

**6.3E+01**

0-  
00+314



CONTINUED FROM -.10500E+02 TO 0. CONTINUED INTERVAL OF .70000E+01 P(19.3) = -.06550E+04 UNITS SCALED BY 100000

①

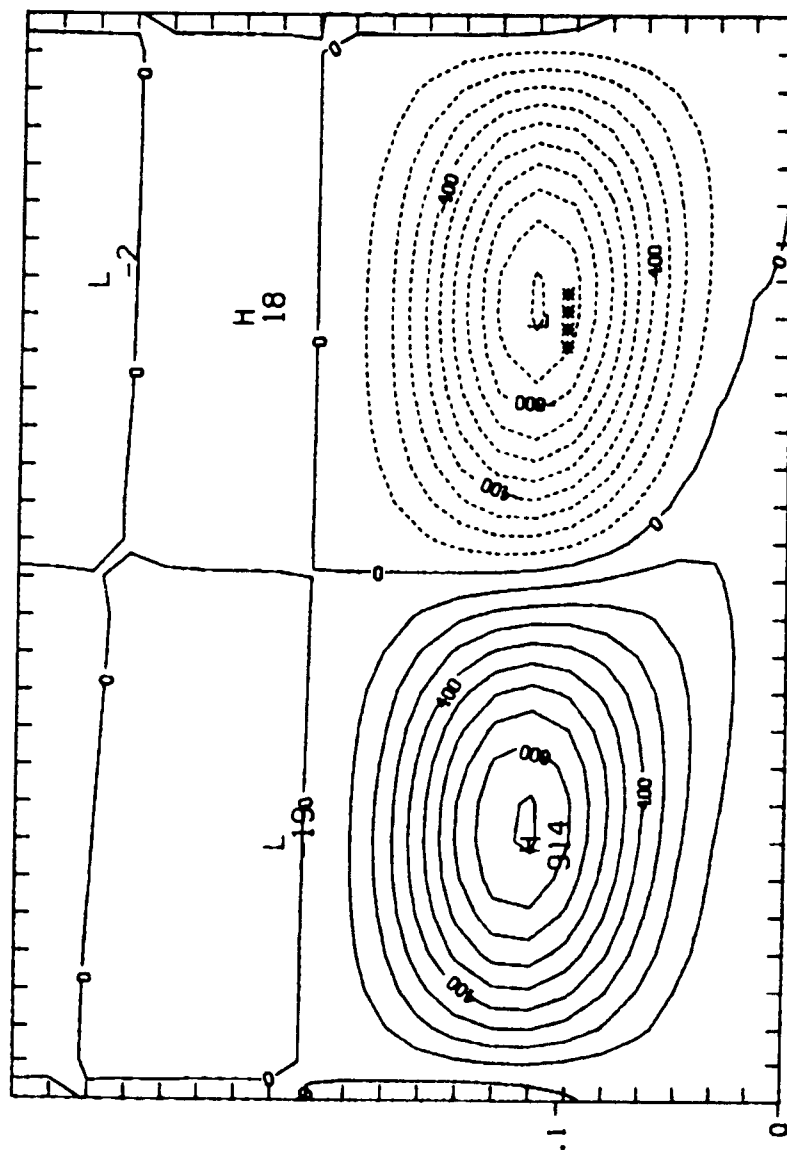
TIME = 2.019E+02 TAUH = 7.857E+00 SEC.

0 0  
-1  
-1E-1  
-4

6.3E+01

MOMENTUM. ADVECTION

$(\vec{v} \cdot \nabla) \vec{v}$  term



CONTour FROM -.10000E-04 TO .60000E-05 CENTER INTERVAL OF .10000E-05 PT(3,3)= .24000E-08 LABELS SCALED BY .10000E-08

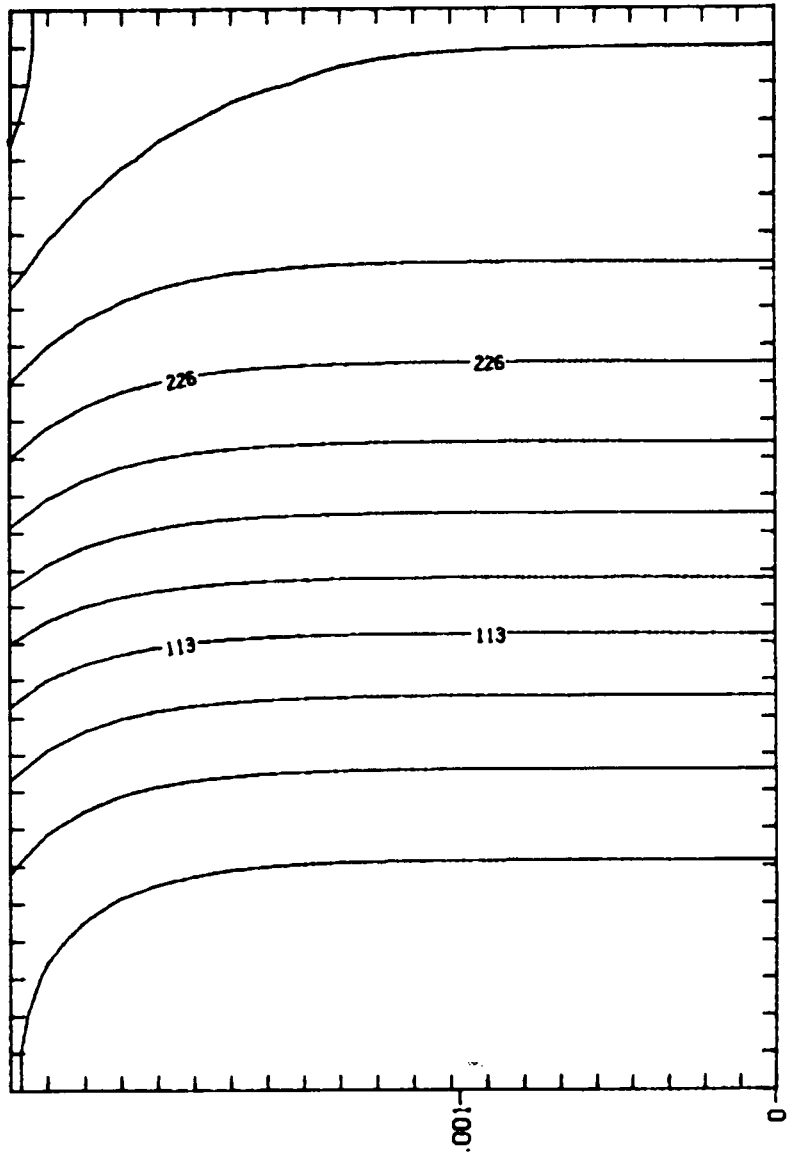
② Resolved

TIME = 2.019E+02 TRIM = 7.857E+00 SEC.  
CONSTANT FLUX CURVES

6.3E+01

2.6E-02

.01 -



CONTOUR FROM 0. TO .58405E+02 CONTOUR INTERVAL OF .28205E+02 P(13.3)= .18945E+01 UNITS SCALED BY 100000

ORIGINAL PAGE IS  
OF POOR QUALITY

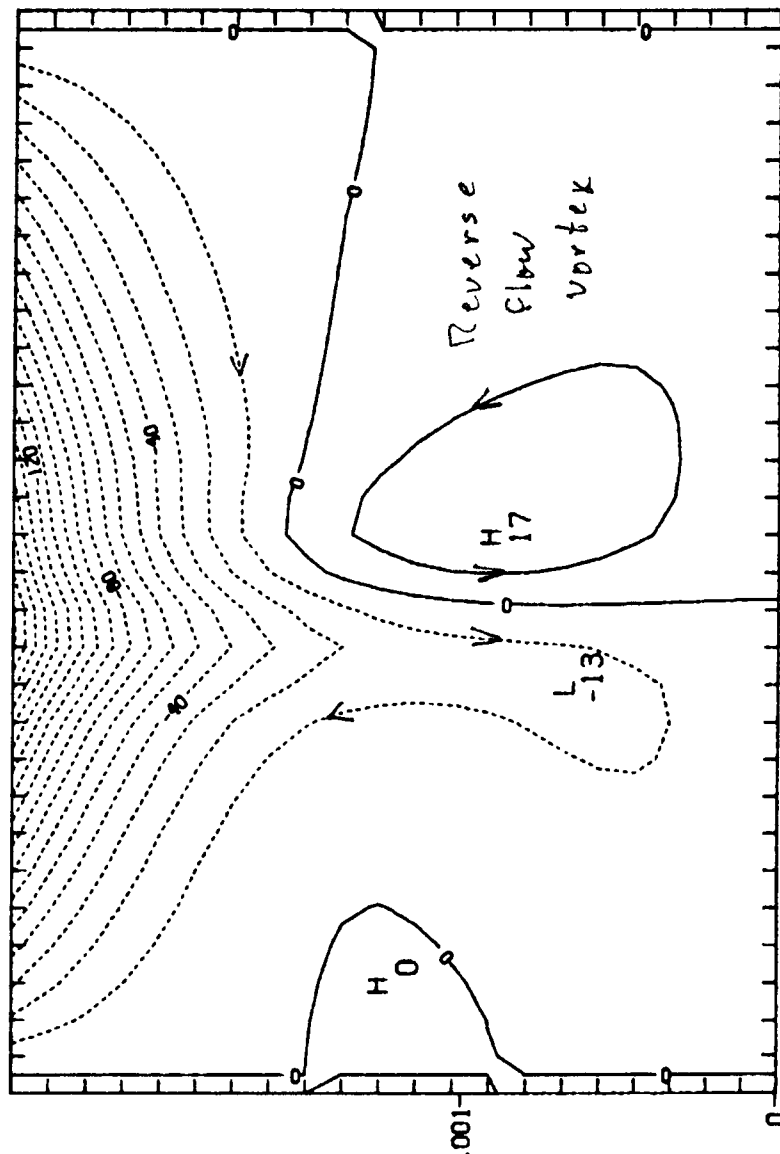
2

TIME = 2.019E+02 TAUH = 7.857E+00 SEC.  
 0 VELOCITY STREAM FUNCT. MAX = -1.715E-04

2.6E-02  
 0  
 -1

6.3E+01

.01 -



CONTINUED FROM -1.7000E-03 TO .1000E-04 CONTINUED INTERVAL OF .1000E-04 PT(19.31) = -.7772E-08 UNITS SCALED BY .1000E-07

ORIGINAL PAGE IS  
 OF POOR QUALITY





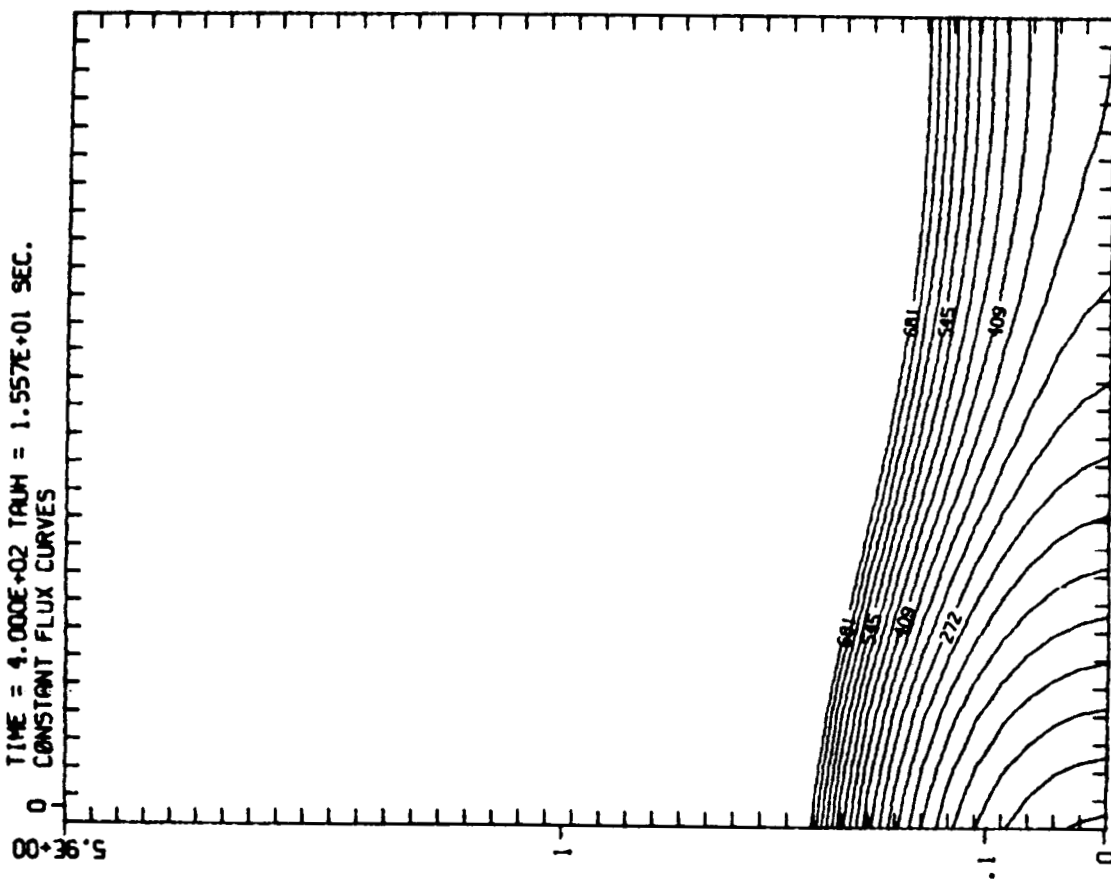
### B. Development of the Petschek regime

The solutions are again initiated with the same linear mode, but the boundary conditions along boundary D-A in the above figure are modified to permit an outflow. As shown in set (3), a continuous outflow develops when the resistive layer is not resolved. However, when sufficient grid points are located within the layer, as shown in set (4), ~~the~~ an outflow initially develops but eventually the nonlinear terms prevent the formation of a regime with outflow along D-A.

③ Insufficient resolution

TIME = 4.000E+02 TRAJ = 1.557E+01 SEC.  
0 CONSTANT FLUX CURVES

6.3E+01



CONTINUED FROM 0. TO .00100E+01 CONTINUED INTERVAL OF .94052E+02 PLUS 312 .35794E+02 LABELS SCALED BY 10000.

ORIGINAL PAGE IS  
OF POOR QUALITY

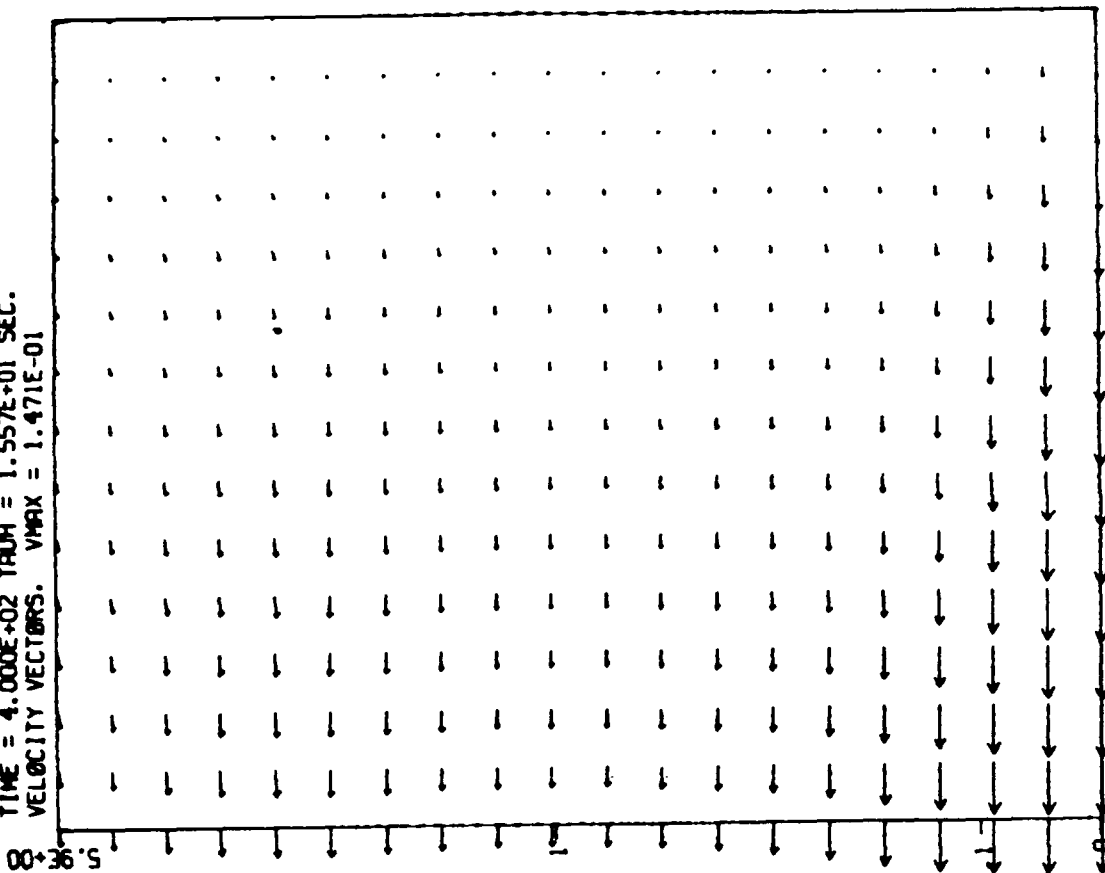
6.3E+01



③

3

TIME = 4.000E+02 TRUM = 1.557E+01 SEC.  
VELOCITY VECTORS. VMAX = 1.471E-01



1.47E+00  
VELOCITY VECTOR

ORIGINAL PAGE IS  
OF POOR QUALITY

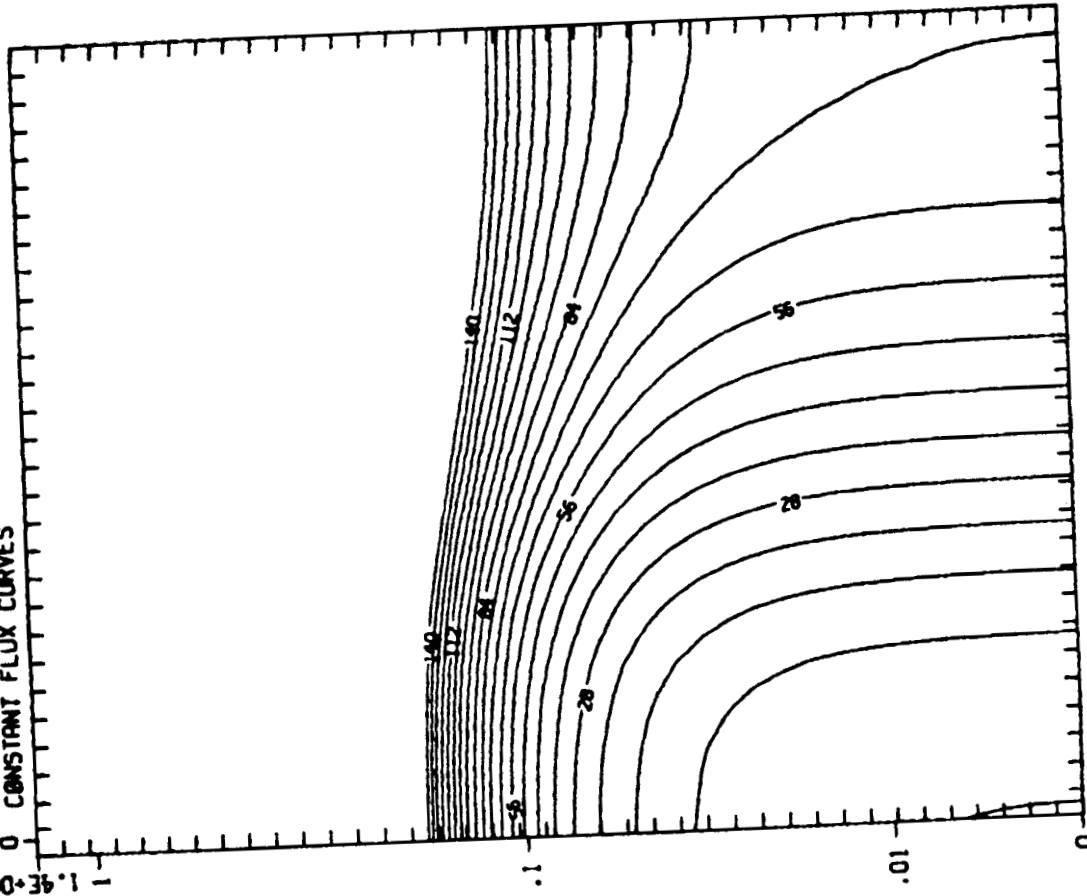
④

Sufficient numerical resolution

TIME = 4.451E+02 TRUM = 1.732E+01 SEC.  
0 CONSTANT FLUX CURVES

6.3E+01

17.3 sec.

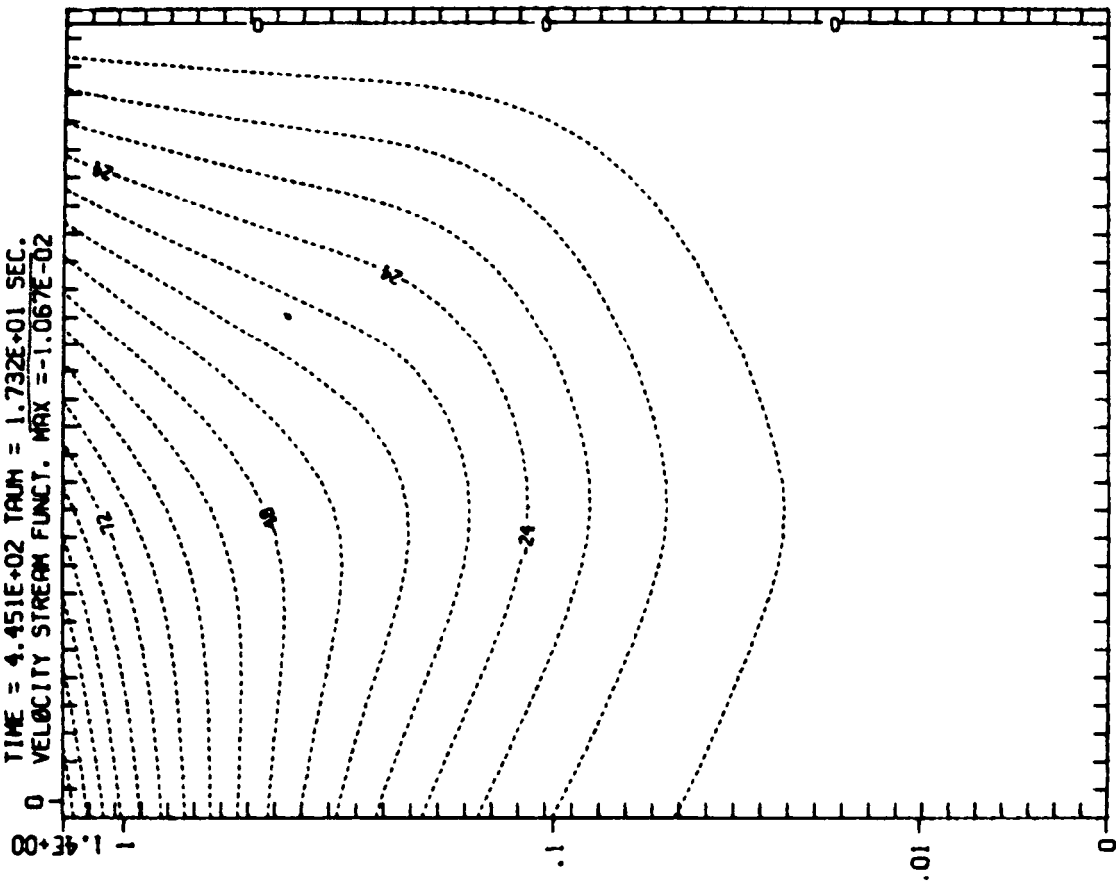


CURVES FROM 0. 16 .1401E-01 CURVE INTERVAL OF .7000E-03 PT(3.31) .4700E-04 LEVELS SOLID BY 10000.

ORIGINAL PAGE IS  
OF POOR QUALITY

7

TIME = 4.451E+02 TAUM = 1.732E+01 SEC.  
0 VELOCITY STREAM FUNCT. MAX = -1.067E-02



6.3E+01

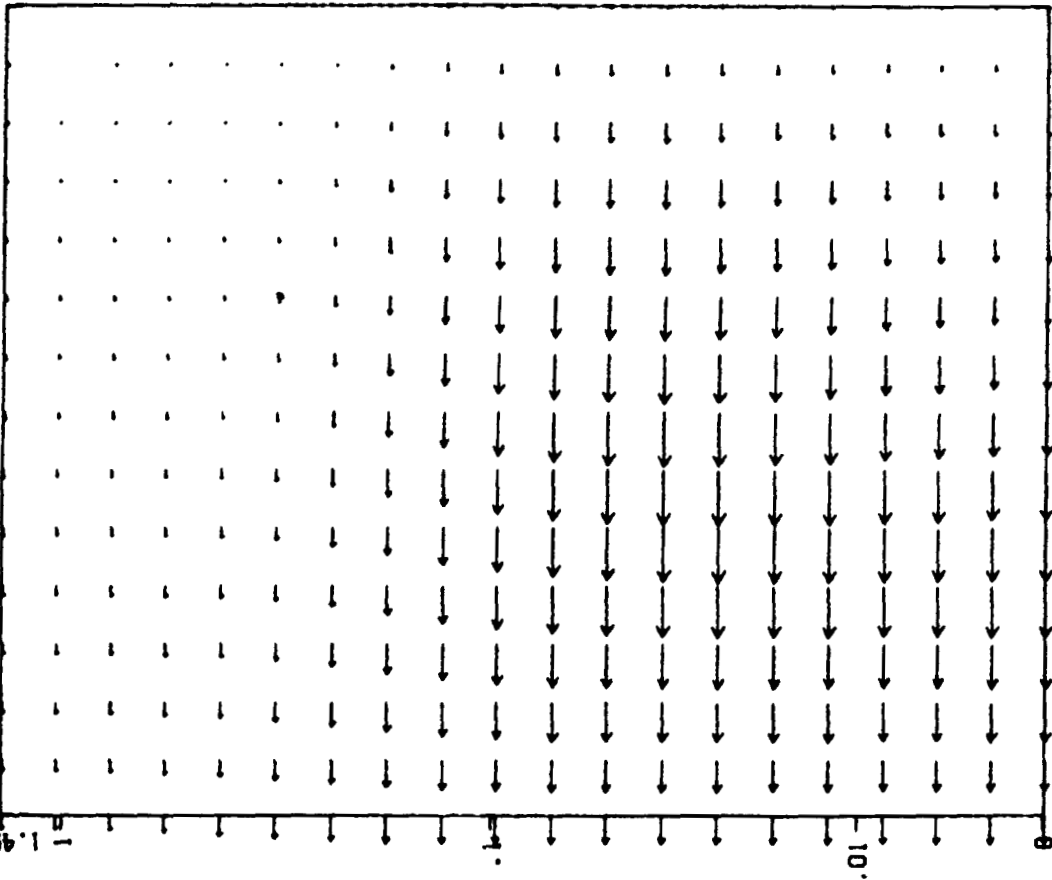
17.3 sec

ORIGINAL PAGE IS  
OF POOR QUALITY

CONTour FIGH -1.0200E-01 TO 0. CONTour INTERVAL OF .8000E-03 PT(13,3) = -.3442E-04 LINE(13) SCALED BY 10000.

④

TIME = 4.451E+02 TRAJ = 1.732E+01 SEC.  
VELOCITY VECTORS. VMAX = 2.300E-02

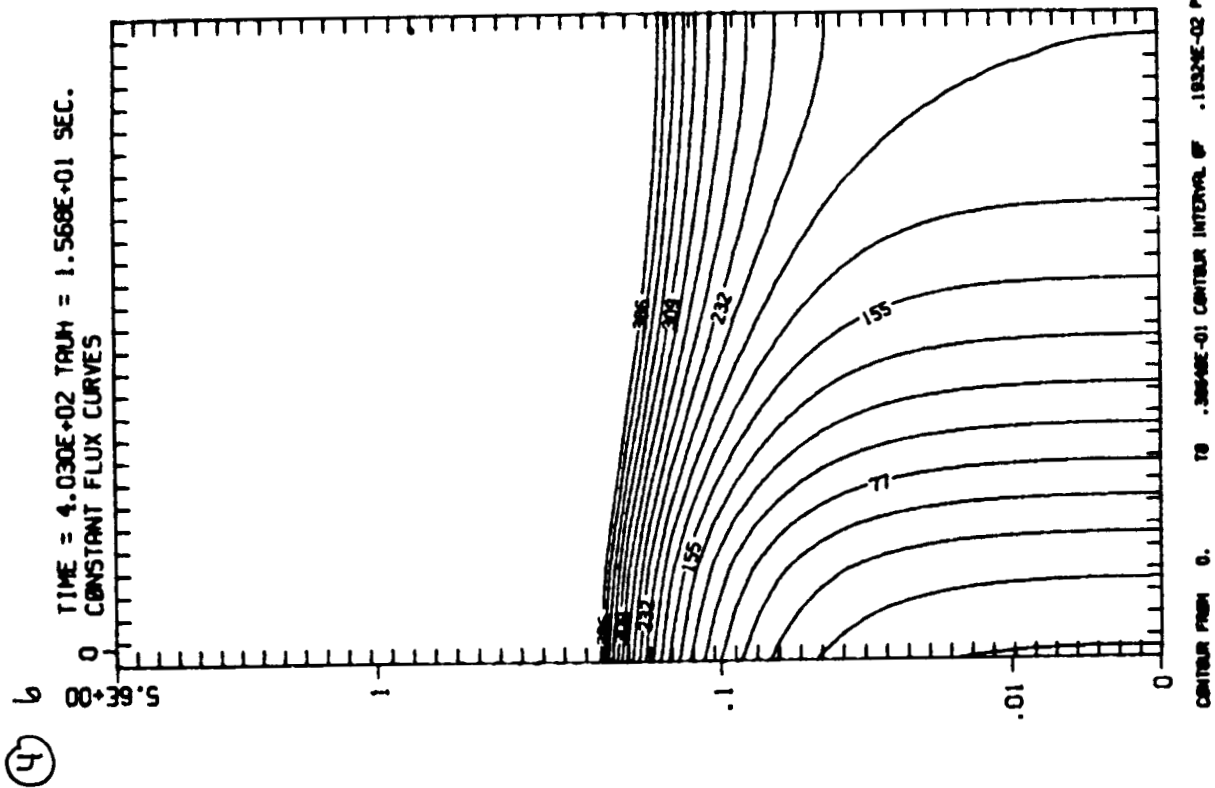


17.7 sec

ORIGINAL PAGE IS  
OF POOR QUALITY

230E-01  
10-20E-02  
VELOCITY VECTORS





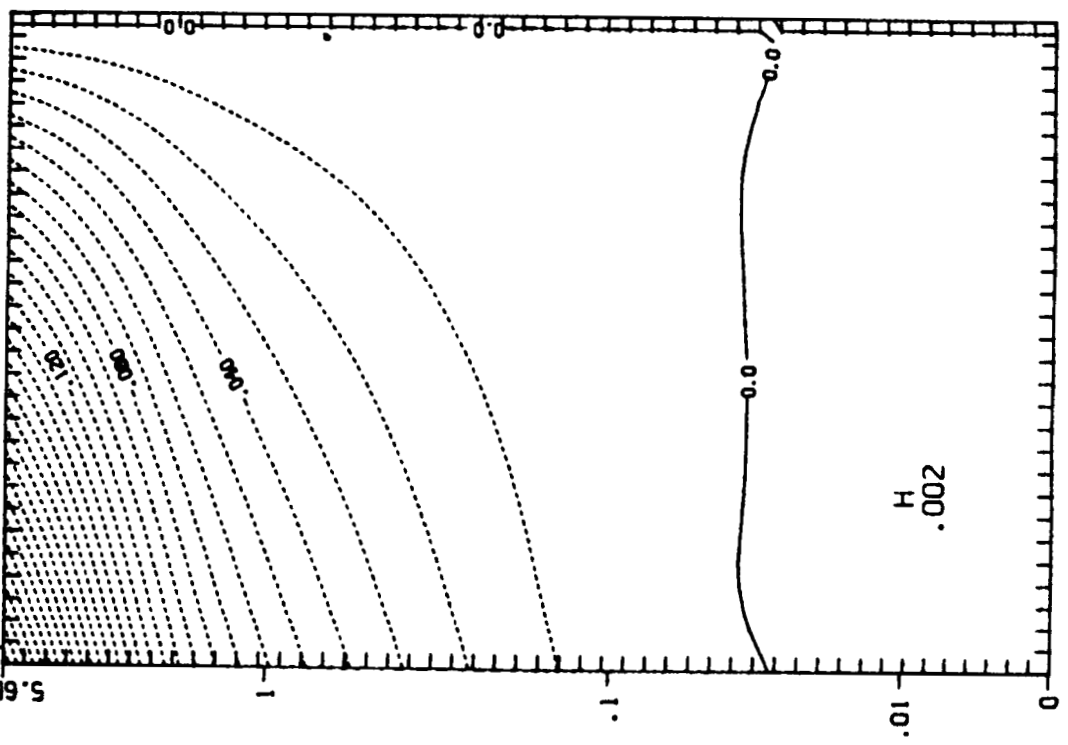
ORIGINAL PAGE IS  
OF POOR QUALITY

4

TIME = 4.030E+02 TRAJ = 1.568E+01 SEC.  
 0 VELOCITY STREAM FUNCT. MAX = -2.860E-01

6.3E+01

33 sec

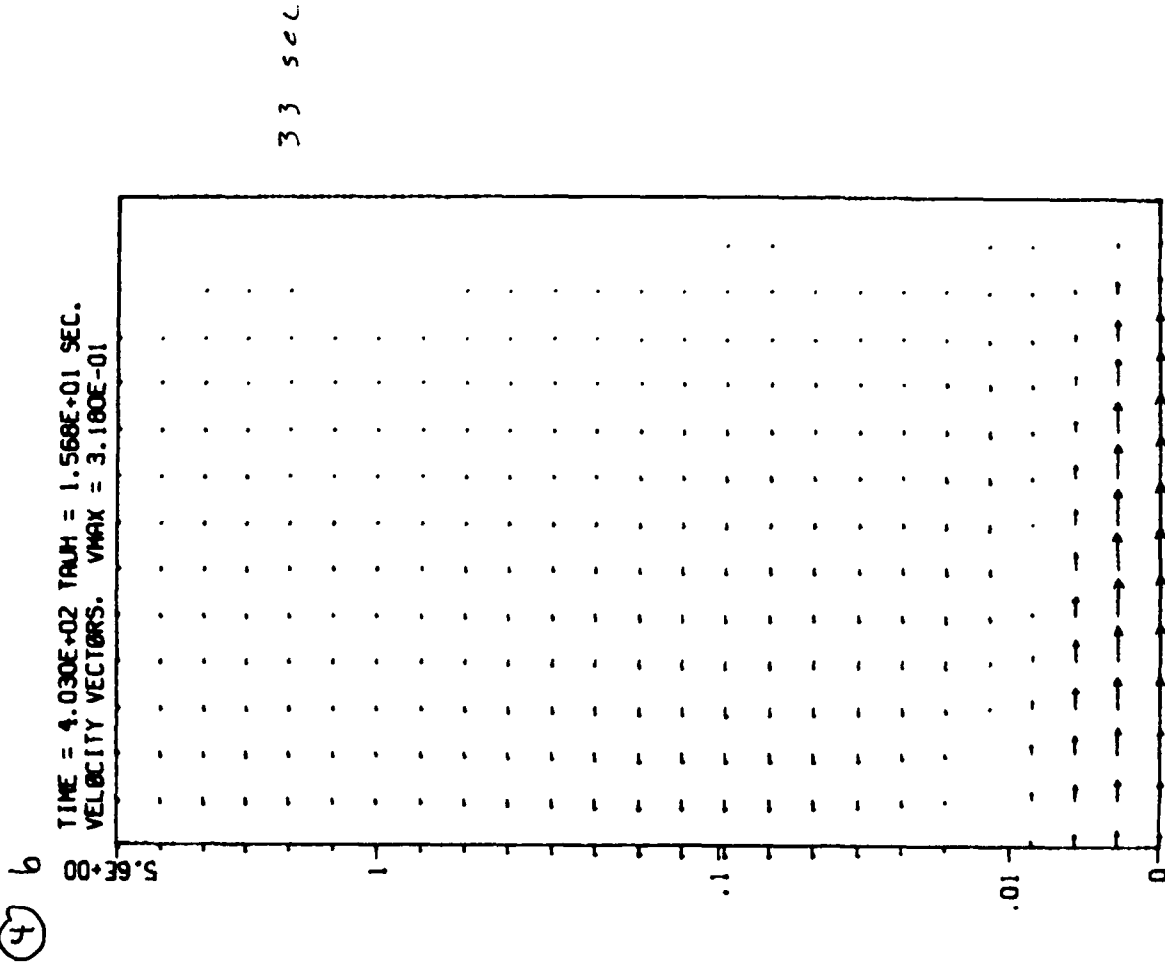


CONTOUR FROM -2.8600 TO 1.5680 CONTOUR INTERVAL .10000E-01 PT(3,3) = .38021E-00

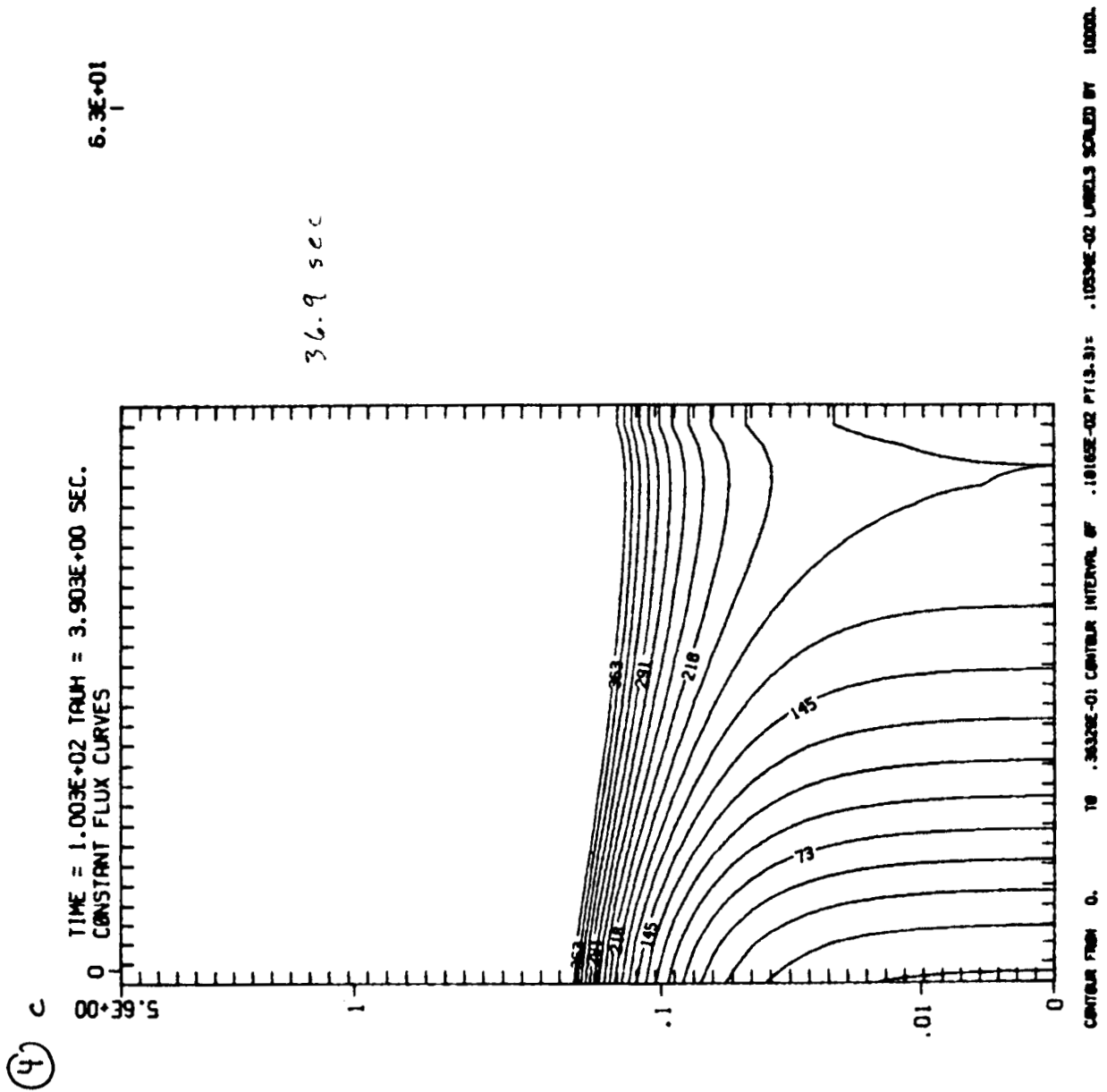
ORIGINAL PAGE IS  
 OF POOR QUALITY

ORIGINAL PAGE IS  
OF POOR QUALITY

312-40  
SECTION VECTOR



ORIGINAL PAGE IS  
OF POOR QUALITY

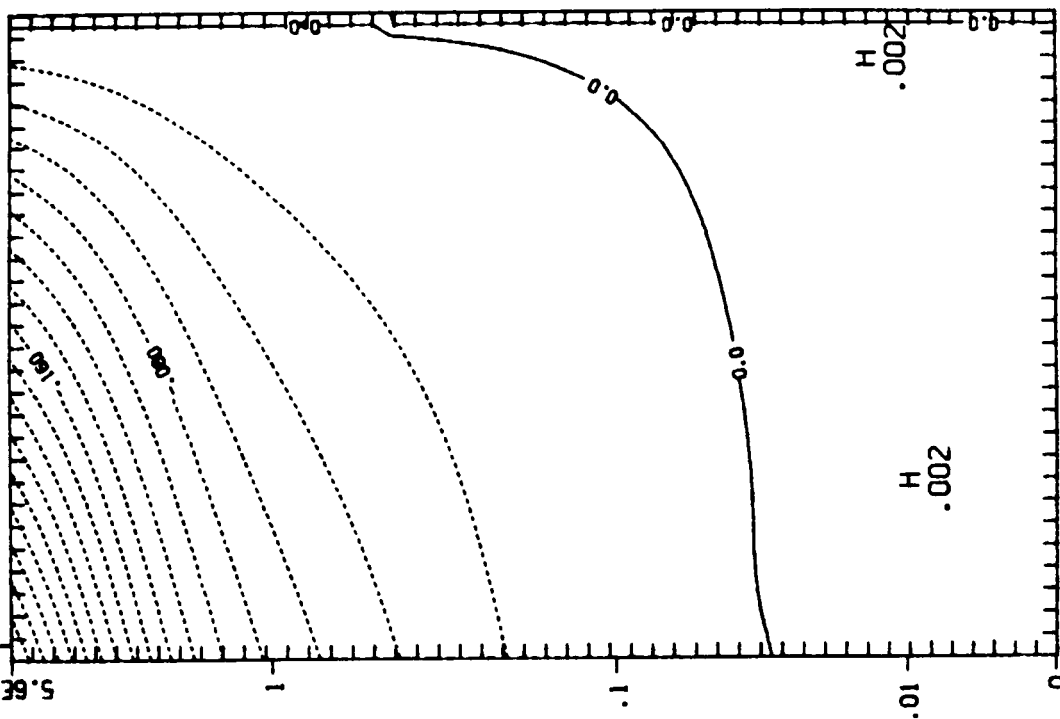


(4)

TIME = 1.003E+02 TAUH = 3.903E+00 SEC.  
0 VELOCITY STREAM FUNCT. MAX = -3.427E-01

6.3E+01

36.9 sec



CONTOUR FROM -.34000 TO 0. CONTOUR INTERVAL OF .20000E-01 PT(3,3)= .42071E-08

ORIGINAL PAGE IS  
OF POOR QUALITY

ORIGINAL PAGE IS  
OF POOR QUALITY

ANALYSIS  
00-2020  
MAXIMUM VELOCITY

